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It has seemed important to call attention to the cause of the roundness of the orbits of the planets and satellites, because it appears likely that the criteria now introduced may go far toward clearing up the mystery which has always surrounded the origin of the solar system.

In all the celebrated speculations of the distinguished astronomers who have occupied themselves with the genesis of our solar system, four phenomena have ever been foremost: (1) The great circularity of the orbits; (2) The small inclinations and the common direction of the orbital motion; (3) The smallness of the attendant planets and satellites compared to the large central masses which govern their motions; (4) The regularity and order everywhere found in our system, the distances, masses, and mutual relations of the orbits being such as to secure maximum stability and perpetuity. All these phenomena and many others are now perfectly explained by a simple theory, which also conforms to the laws of spiral development observed in the sidereal universe. A simple and obvious theory which accounts for the known phenomena while all other theories are involved in contradiction, will naturally have a strong claim to acceptance. Indeed we cannot refuse our assent to it without violating the recognized rules of natural philosophy as formulated by NEWTON in the *Principia*.

U. S. NAVAL OBSERVATORY,
MARE ISLAND, CAL., January 30, 1909.

PHOTOGRAPHS OF COMET *c* 1908 (MOREHOUSE)

BY A. ESTELLE GLANCY.

From September 19th until December 15th, at which latter date the comet could be followed only long enough to photograph the head, exposures have been made at the Lick Observatory on every favorable occasion. Successful exposures were made on twenty-eight nights. The nights omitted were unfavorable,[1] by reason of too strong moonlight, clouded sky, or high winds. The Crocker photographic telescope was used in this work. This instrument carries two cameras,—a Willard lens of 15.2$^{\text{cm}}$ (6.0 inches) aperture and 78.28$^{\text{cm}}$ (30.82 inches) focal length, and a Dallmeyer lens of the same aperture and 82.6$^{\text{cm}}$ (32.52 inches) focal length. Hence the scale value of the plates taken with the Willard lens is $1^\circ = 1.37^{\text{cm}}$ (0.538 inch) and that of the Dallmeyer is $1^\circ = 1.44^{\text{cm}}$ (0.568 inch). As soon as the comet had increased sufficiently in brightness to allow of a reasonably short exposure time, it was planned to use the Willard camera for one plate of fairly strong density, and simultaneously to expose in the Dallmeyer camera two plates, each of one half the exposure time with the Willard camera. By this arrangement each camera was made to serve a different purpose. The Willard plate gives a strong image of the general appearance of the comet, including the fainter portions of the tail; the Dallmeyer plates give more truthfully the actual conditions existing at a given time and permit comparisons to determine the motions of condensations or other details of structure in the tail of the comet. It has been recognized for several years that intervals of twenty-four hours are too long to detect the rapid transformations which take place in comets; and a superficial examination of the Willard plates shows this to be particularly true of Comet Morehouse. So different are some of these plates from the one taken on the preceding or the following day that no indications of identity are visible at first sight.

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[1] The number of unfavorable nights was unusually large this year.

Below is a tabulation of the series of Lick Observatory plates, which may be of service to observatories in other longitudes:—

Pacific Standard Time. 1908.	Willard Camera.		Dallmeyer Camera.	
	Middle of Exposure.	Duration.	Middle of Exposure.	Duration.
Sept. 19.	10^{h} 28^{m}	3^{h} 0^{m}	10^{h} 28^{m}	3^{h} 0^{m}
27.	9 33	1 30	9 33	1 30
27.	12 40	1 30	12 40	1 30
29.	8 56	1 32	8 56	1 32
29.	11 20	1 30	12 8	3 5
29.	12 54	1 29	.. ..	.. ..

Pacific Standard Time. 1908.	Willard Camera.				Dallmeyer Camera.			
	Middle of Exposure.		Duration.		Middle of Exposure.		Duration.	
Oct. 16.	10	20	1	38	9	54	0	47
	..	..	..	..	10	45	0	48
18.	7	58	1	31	7	58	1	31
20.	9	27	2	44	8	45	1	20
	..	..	..	..	10	9	1	20
21.	8	12	2	46	7	30	1	22
	..	..	..	..	8	54	1	21
22.	10	0	2	35	9	19	1	12
	..	..	..	..	10	38	1	20
23.	8	12	2	44	7	28	1	16
	..	..	..	..	8	51	1	26
24.	8	8	2	44	7	24	1	16
	..	..	..	..	8	47	1	26
25.	8	26	2	21	7	24	1	15
	..	..	..	..	8	50	1	34
26.	7	6	0	36	7	6	0	36
27.	8	50	2	49	8	10	1	15
	..	..	..	..	9	34	1	22
28.	..	..	..	..	8	46	1	1
	..	..	..	..	9	54	1	13
30.	10	25	1	16	10	2	0	30
	..	..	..	..	10	40	0	45
Nov. 10.	6	58	1	5	6	46	0	45
	..	..	..	..	7	20	0	20
11.	6	52	1	32	6	28	0	45
	..	..	..	..	7	16	0	45
12.	7	57	1	54	7	25	0	50
	..	..	..	..	8	26	0	57
13.	7	37	1	42	7	11	0	50
	..	..	..	..	8	3	0	50
14.	7	6	1	40	6	41	0	50
	..	..	..	..	7	33	0	46
15.	7	5	2	10	6	25	0	50
	..	..	..	..	7	38	1	4
16.	7	21	2	42	6	25	0	50
	..	..	..	..	7	31	1	0
	..	..	..	..	8	22	0	40

Pacific Standard Time. 1908.	Willard Camera.		Dallmeyer Camera.	
	Middle of Exposure.	Duration.	Middle of Exposure.	Duration.
Nov. 17.	7 24	2 43	6 28	0 50
	.. ..	.. ..	7 22	0 55
	.. ..	.. ..	8 20	0 53
18.	7 1	1 52	6 30	0 50
	.. ..	.. ..	7 27	1 0
27.	7 16	1 8	7 16	1 8
28.	7 10	0 44	7 10	0 44
Dec. 10.	6 24	0 29	6 24	0 29
11.	6 27	0 22	6 27	0 22
12.	6 21	0 24	6 21	0 24

The four photographs selected for reproduction were chosen because of their striking appearance. The first and fourth belong respectively to the earlier and later half of the period under observation; the second and third occurring near the middle of the series, demonstrate the changes which may be expected in two days. Since no reproduction by mechanical processes can do justice to the original negatives, a description of these four plates is given to supplement the illustrations.

October 24th.—The comet appears on this date in one of its quieter phases. In the line of strongest expulsion from the head is a long, narrow, dense streamer. On the following side, a broad, heavy streamer extends about 4°.6. On the preceding side, a like streamer of greater density and breadth extends out to 10°. About 3° from the extremity there is a sharp bend in the same direction in which the radius vector[1] is moving. There are two undulations about 2° from the head, and a noticeable bulging at a distance of about 4°.5. Faint line-streamers and one fan-shaped streamer lie outside the main tail. The activity in the head is seen to continue well around on the side toward the Sun.

November 16th.—This plate is one of a group showing very rapid changes. The tail belongs to the type frequently noticed, a central helical structure and outlying, long, narrow streamers. The general direction of the tail is one of continued

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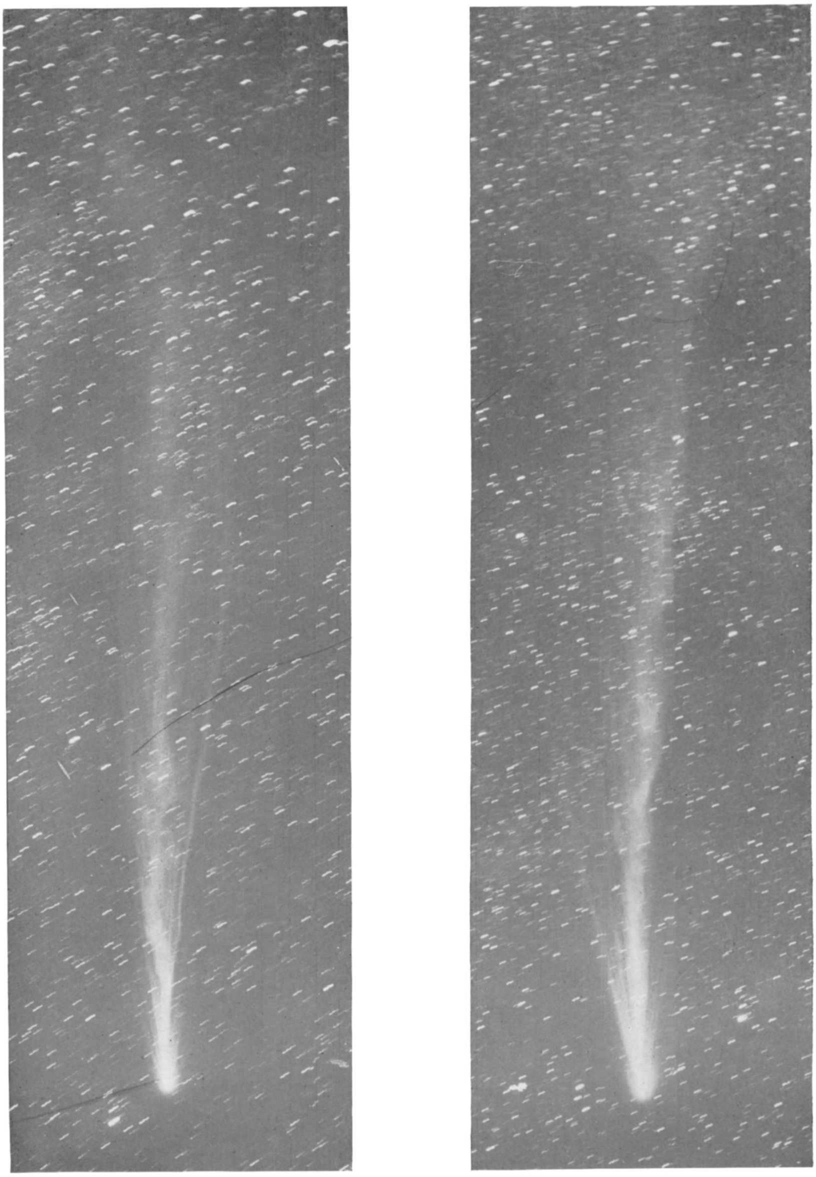
[1] The radius vector is the line joining the Sun and comet. As the comet moves in its orbit this line moves forward also.



Nov. 16, 1908. 7h 21m P. S. T.

Nov. 18, 1908. 7h 1m P. S. T.

Comet C 1908 (Morehouse).

curvature for about 7°. The curvature shows that the tail is lagging behind the radius vector. From 7° to 11° the tail is bent in the opposite direction. The breadth of the tail is due to many diffuse and divergent faint streamers. The matter which is puffed out, as it were, appears to come from the sharp apex of a cone. The clear-cut edges of the cone are outlined by single streamers. Within the cone is a dense, wavy streamer which inclines toward the following side of the cone for about 1°, and then shifts to the opposite side, breaking out into the more pronounced spiral structure. The spiral increases in dimensions until it is finally broken up by the diffusion of the matter composing it. One is reminded of the extraordinary outburst which occurred on October 15th on a larger scale. One fine streamer within the cone appears distinctly severed; the broken ends are thrust far apart. It is worth noticing that the heavy bright streamer whose outer extremity is about 5° from the head, and whose inner extremity appears to be disconnected from the main tail, has appeared within twenty-four hours. No streamer on the plate of November 15th can be identified with it. Short, straight, and more divergent streamers define the boundaries of the tail near the head. The head itself is unusually small, showing both nucleus and coma.

November 18th.—In general appearance this plate resembles that of November 17th, but only in type, for there are no points of identity immediately recognizable. Nearly all the matter composing the tail seems to lie in a well-defined cone with an angle of about 21°. The central portion is very bright and of varying density. The outer parts are composed of many line-streamers, the greater number of these lying on the preceding side. The spiral structure is not so definitely suggested on this plate as on some of the other plates. The source of the densest stream of matter seems to be the well-defined apex of a smaller cone within the cone mentioned above. A large-scale plate might prove this to be an apparent rather than a real effect. The general direction of the tail shows that it is lagging behind the radius vector. On the following side the streamers are few and relatively short, thus leaving a boundary defined by the brightest portions of the tail. On the preceding side the streamers diverge at an unusually large angle from the main tail. On November 17th a similar group of streamers was prominent, but the deviation from the main direction was less. It should be noted that parts of the main tail and the outlying streamers often have corresponding irregularities of structure. The head appears larger than on November 16th, and is active over the greater part of its circumference.

November 27th.—The definition of the photograph is marred by fogging, due to strong moonlight, but what I have called the spiral structure is so well marked that this plate was chosen in preference to other more perfect ones. The tail structure is like that of November 16th. Within the numerous divergent streamers is a narrow cone of luminous matter. About 0°.4 from the head it bulges and the wavy streamers (perhaps there is but one, which is very erratic) appear to shoot out in a conical helix, which is finally dissipated in a broad diffuse flare.

Such a wealth of like data has been gathered by many observers in America and Europe that an unusually complete history of the comet's behavior may be constructed. Certainly no earlier comet has been subjected to such exhaustive observations. Photography finds an important usefulness in comet work, and Comet Morehouse is a remarkably favorable subject for two reasons. In the first place, the orbit plane could scarcely be better situated with respect to the Earth. With an inclination of 140° to the ecliptic, it cuts the equator a little east of the winter solstice, and the point of perihelion passage lies but a little south of the equator. Perihelion passage occurred on December 26th. Hence, from September 1st to December the comet was visible in the northern hemisphere, and during the early part of this period it was a circumpolar object. Five weeks after its disappearance below our horizon it became visible to the southern observers under almost as favorable circumstances, and it can be followed for several months more. Though visually fainter than Comet Daniel 1907, Comet Morehouse photographed more readily. This is due to the fact established by spectroscopic observations here and elsewhere, that the radiations lying in the visual regions of the spectrum (red, orange, yellow, green) are weak and those in the photographic regions (blue and violet) are remarkably strong. Hence this comet, which appears in the visual telescope as an object of little interest, has secured the continuous attention of numerous observers.

Several months still remain in which material for study will be collected, and it is too early to know the results of the evidence already at hand. But it is believed that the photographic records of the comet's behavior will increase greatly our general knowledge of comets and bear especially strongly upon present theories regarding tail formation.

Extensive series of photographs have been taken by the observers at Greenwich, by M. Quénisset and M. Baldet at the observatory of Juvisy, and by Professor Barnard at Williams Bay. And no doubt the German observers and others have been photographing the comet. Extraordinary outbursts were recorded by one or more observers on or about September 16th and 30th and October 1st, 6th, and 15th. It is regretted that because of less favorable weather, none of these dates are included in the Lick Observatory series.

However, perhaps occasional astonishing transformations show no more remarkable cometary activity than the less conspicuous and more frequent developments. And it is probable that the recurrent types of activity will help most in the solution of the problem of tail formation. An early statement on this subject is made by the Astronomer Royal of England in connection with a preliminary examination of the Greenwich plates.[1] He says: "A study of the photographs shows that the form of the comet's tail exhibits a recurring series of phases, and that the phase seems to bear a relation to the condition of the nucleus which passes through cycles of stages of alternating activity and quiescence. At the stage of quiescence the comet presents the appearance of a nucleus with little enveloping coma, and straight streamers passing away at little inclination to the general direction of the tail. The coma then grows, envelopes form about the nucleus (on the side towards the Sun), and the rays of the tail become more spread. The stage of maximum activity is now reached, and larger quantities of matter appear to be expelled from the head and then driven back, forming a bright wavy tail, the streamers being no longer straight, but greatly disturbed. The bright tail then appears to be driven off and the stage of quiescence follows."

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[1] *Monthly Notices R. A. S.*, **69**, 52, 1908.

The presence of parabolic envelopes about the nucleus, such as have been seen in the large comets, is well established by the Greenwich plates. It is interesting to know that so complete is the Greenwich series of photographs that the development of these envelopes into straight rays can be watched and that the physical changes in the tail can be followed. The series of plates on which are shown the details of the coma and that portion of the tail near the head were made with the reflecting telescope of thirty inches' aperture and are, therefore, large-scale photographs. Before the above-quoted article was read, one of the Lick Observatory plates was noticed to show traces of a parabolic envelope, but so uncertain was the appearance that it was considered to be possibly only a photographic effect.

Other facts about the Lick Observatory photographs are equally interesting. Perhaps the most striking fact is the frequent occurrence of that type of tail structure which is shown in three of the illustrations. It appears as if the tail were more or less irregularly cone shaped, a skeleton conical surface being formed by long, comparatively straight shafts of luminous matter ejected from a small area of the nucleus. Having the same axis and smaller conical dimensions, there appears to be a helix of dense matter which, receding from the nucleus, expands from a tightly compressed stream into a diffuse spiral until the structure is lost in the dissipation of the material forming it. This action has been likened by Dr. CAMPBELL to the flame from a waving torch.

An interesting group of plates falls between the dates November 13 and November 18, inclusive. One image of the comet is entirely different from the next one, but of recurrent type. More resemblance exists between two plates of forty-eight hours' interval than between an intervening plate and either of these two. Long, bright streamers appear and disappear in twenty-four hours. For instance, the long streamer

5° in length in the illustration of November 16 appeared subsequent to the exposure of November 15. At any rate, there is no streamer on the earlier plate with which it can reasonably be identified. If we assume that matter has been ejected to a distance of 5° in one day, the average velocity of recession from the nucleus is greater than ninety miles per second, for ninety miles per second is roughly the velocity in the direction of the tail projected upon a plane at right angles to the line of sight. That the phenomenon is an effect of rotation is also difficult to conclude. Photographs taken at other observatories during this interval would help solve the problem.

Without doubt, the comparison of plates will show acceleration in the motion of recession from the head. One such rough measure has been made from a reproduction of a photograph[1] taken at the Observatory of Juvisy on October 16th, 7^h 45^m, Paris Mean Time, and two photographs taken at the Lick Observatory, October 16th, 10^h 20^m, and October 18th, 7^h 58^m, Pacific Standard Time. Approximate measures were made on the broadening of the tail. The distances on the three plates are 1°.5, 1°.9, and 4°.3. The resulting average velocities of recession from the head in the direction of the tail are twenty-seven miles (44^{km}) and thirty-six miles (58^{km}) per second for the first and second intervals, respectively.

Much work remains to be done, and the detailed results will be published in a subsequent *Lick Observatory Bulletin.*

LICK OBSERVATORY, January 28, 1909.

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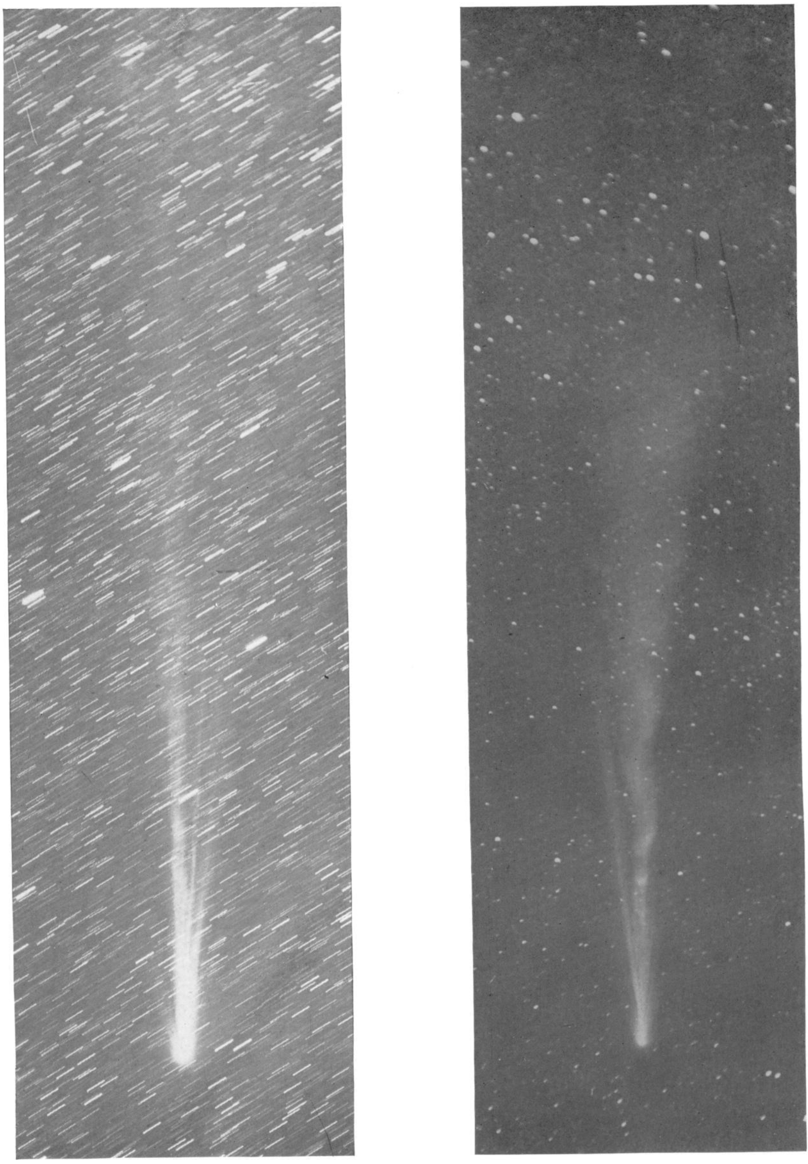
[1] *Ccmptes Rendus,* **147,** 1035.



Oct. 24, 1908. 8h 8m P. S. T.

Nov. 27, 1908. 7h 16m P. S. T.

COMET C 1908 (MOREHOUSE).